REMARKS

Claims 1-14 and 21-27 are pending. By this Amendment, claims 1, 2, 8, 9, 21, 22, 25 and 27 are amended. The amendments to claims 1, 8, 21 and 25 are supported by the specification at, for example, pages 21 and 22. No new matter is introduced by the present Amendment.

In the Advisory Action dated February 23, 2006, the Examiner included a Notice of Non-Compliant Amendment, and indicated that the Amendment filed on February 14, 2006 was not entered. The present Amendment address all of the issues raised by the Examiner in the Final Office Action dated February 14, 2005, and the Advisory Action dated February 23, 2006. As such, only this Amendment should be entered.

In the Final Office Action, the Examiner objected to the specification asserting that "it is not clear how a methylene group, which is divalent, can be replaced with groups that are not divalent." In the previous response, Applicants submitted, and continue to maintain, that one of ordinary skill in the art would recognize that the substituted group would be inserted in the methylene chain in such a way as to provide the appropriate number of bonds to each group. In response, the Examiner asserted that "Applicants' assertion is merely attorney argument that is not supported by any objective evidence on the present record. The instant specification merely discloses that one of the methylene groups in the group $-(CH_2)_nH$ can be replaced by N, C, B, Si, P or a 'CR_b'." However, Applicants note that the specification expressly teaches that "**one or more** of the methylene groups is optionally replaced by O, S, N, C, B, Si, P, C=O, O=S=O….." (Emphasis added). See specification at, for example, page 3, lines 5-15.

Since the specification clearly indicates that one or more methylene groups can be replaced, one of ordinary skill in the art would recognize that the substituted groups would be

inserted into the methylene chain so as to provide the appropriate number of bonds to each group. Furthermore, no objective evidence is needed on this point, since clearly one of ordinary skill in the organic synthesis art would recognize that a substituted group would have to be inserted in a way to provide the appropriate number of bonds to the group. Additionally, Applicants note that "[t]he specification need not disclose what is well known to those skilled in the art…." See MPEP § 2164.05(a).

Thus, since one of ordinary skill in the art would be able to understand how a divalent methylene group could be substituted with an appropriate combination of disclosed atoms and groups, the specification is clear and Applicants respectfully request the withdrawal of the objection to the specification. However, Applicants have amended the specification to remove some inadvertent redundancy in the notation.

The Examiner also objected to the specification asserting that when the R group of, for example, an NR_a group is a bond, "it is not clear to what the R groups in the groups are bonded." Applicants submit that generally the term "a bond" is clear, and that one of ordinary skill in the art would recognize that when an R group is a bond, the bond is between adjacent groups in the methylene chain. However, in order to advance prosecution, Applicants have removed the bond language from the description of the R groups in the specification. As such, the Examiner's objection to the specification is presently moot.

The Examiner also objected to the specification asserting that "it is not clear what is meant by the term 'part of a ring group.'" Applicants' continue to maintain that one of ordinary skill in the art would generally understand that "part of a ring group" is an atom or group that is

bonded to other atoms or groups in a ring system. This terminology is discussed below in regards to the rejection under 35 U.S.C. § 112.

Rejections Under 35 U.S.C. § 112, Second Paragraph

The Examiner rejected claims 1-14 and 21-27 under 35 U.S.C. § 112, second paragraph, as being indefinite. More specifically, the Examiner asserted "it is not clear what is meant by the term 'part of a ring group.'" Applicants maintain that the one of ordinary skill in the art would generally understand that "part of a ring group" is an atom or group that is bonded to other atoms or groups in a ring system, and as such the term "part of a ring group" is definite. Additionally, Applicants have attached to this response several web prints outs relating to the term "part of a ring structure." As used throughout the attached prints outs, the term "part of a ring structure" relates to an atom or group bonded to other atoms or groups to form a ring system. Moreover, U.S. patent subclass 536/26.11 relates to compounds where "phosphorous is part of a ring." For example, U.S. Patent No. 6,812,342 is classified in subclass 536/26.11, and Figs 2 and 3 of the '342 patent depict a phosphorus group forming part of a ring structure (i.e., bonded to other atoms or groups in a ring). Thus, the term part of a ring structure or group is understood by one of ordinary skill in the art, and by the PTO, to mean an atom or group that is bonded to other atoms or groups to form a ring system. Since one of ordinary skill in the art would understand the scope of the term "part of a ring group," claims 1-14 and 21-27 are definite.

The Examiner also rejected the claims 1, 8, 21 and 25 as being indefinite asserting that "it is not clear how a methylene group, which is divalent, can be replaced with groups that are not divalent." As an initial matter, Applicants note that the claims recite that the methylene groups

can be replaced by, for example, a CR_cR_d group or a SiR_eR_f, and thus reciting groups such as C and Si is redundant. Thus, Applicants have removed the redundant groups from the claims. As discussed above, Applicants continue to maintain that one of ordinary skill in the art would recognize that the substituted group would be inserted in the methylene chain in such a way as to provide the appropriate number of bonds to each group. More specifically, Applicants note that the specification expressly teaches that "one or more of the methylene groups is optionally replaced by O, S, N, C, B, Si, P, C=O, O=S=O….." See specification at, for example, page 3, lines 5-15. Since the specification clearly indicates that one or more methylene groups can be replaced, one of ordinary skill in the art would recognize that the substituted groups would be inserted into the methylene chain so as to provide the appropriate number of bonds to each group. However, Applicants have amended the claims to remove some inadvertent redundancy in the notation, and submit that claims 1, 8, 21 and 25 are definite.

The Examiner also asserted that claims 1, 8, 21 and 25 are indefinite "because it is not clear to what R groups are bonded" when the R groups are "a bond." As discussed above, Applicants submit that generally the term "a bond" is clear, and that one of ordinary skill in the art would recognize that when an R group is a bond, the bond is between adjacent groups in the methylene chain. However, in order to advance prosecution, Applicants have removed the bond language from the claims, and submit that the Examiner's rejection of claims 1, 8, 21 and 25 is presently moot.

Since the claims 1-14 and 21-27 are definite, Applicants respectfully request the withdrawal of the rejection of claims 1-14 and 21-27 under 35 U.S.C. § 112, second paragraph, as being indefinite.

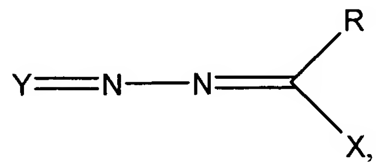
Rejections Under 35 U.S.C. § 103

1. Rejections Over Goto

The Examiner rejected claims 1, 2, 21, 22, 25 and 27 under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent 4,415,640 to Goto (the '640 patent). More specifically, the Examiner asserted that "the substituent group $N-(CH_3)_2$ on one of the phenyl groups of the 9-fluorenylidene group in the Goto compound (11) does not meet the substituent limitations recited in instant claims 1, 21, and 26." The Examiner further asserted that "Goto discloses that compound (11) represents formula (I) disclosed at col. 3, lines 20-47. Goto teaches that both benzene rings in the 9-fluorenylidene group are substituted with the groups X and Y, respectively, where the X and Y groups can be a substituted amino, a halogen, an alkyl group having preferably from 1 to 8 carbon atoms, an amino group, or an alkoxy group having preferably 1 to 8 carbon atoms." The Examiner then concluded that "[i]t would have been obvious for a person having ordinary skill in the art, in the view of the teachings of Goto, to replace the dimethylamino substituent group on the benzene ring in the 9-fluorenylidene group in the Goto compound (11) with an alkyl having 1 to 8 carbon atoms or an alkoxy having 1 to 8 carbon atoms...." Applicants have amended their independent claims to more particularly point out their claimed invention. Applicants submit that the '640 patent does not render Applicants' invention, as presently claimed in independent claims 1, and 21, prima facie obvious.

Compound (11) of the '640 patent comprises a N,N-diethylamine-4-naphthylene group at one end of the compound. Additionally, Formula (I) discloses that R_1 "is a substituted or unsubstituted aryl group, preferably substituted or unsubstituted phenyl or naphthly...." As such, the '640 patent does not teach or suggest a compound where the R_1 is selected from the

group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. In contrast, Applicants' invention, as presently claimed in independent claims 1 and 21, relates to a charge transport material having the formula

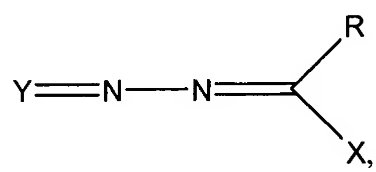


where R comprises a hydrogen, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group and X comprises an arylamine group selected from the group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. Since the '640 patent does not teach or suggest the claimed charge transport materials, Applicants respectfully request the withdrawal of the rejection of claims 1, 2, 21, 22, 25 and 27 under 35 U.S.C. § 103(a) as being unpatentable over U.S. the '640 patent.

2. Rejections Over Ohkubo Combined With Goto

The Examiner rejected claims 7-9 and 14 under 35 U.S.C. § 103(a) as being unpatentbale over U.S. Patent 5,430,526 to Ohkubo (the '526 patent) combined with the '640 patent (Goto). More specifically, the Examiner asserted that the '526 patent "discloses an electrophotographic image forming apparatus comprising all the components recited in the instant claims 8, 9, and 14, but for the particular photoreceptor." Additionally, the Examiner noted that the '526 patent "does not disclose the use of the photoreceptor recited in the instant claims." Applicants submit that the combination of the '526 patent and the '640 patent does not render Applicants' invention, as presently claimed in independent claims 1 and 8, prima facie obvious. Applicants respectfully request reconsideration of the rejection based on the following comments.

As discussed above, Compound (11) of the '640 patent comprises a N,N-diethylamine-4-naphthylene group at one end of the compound. Additionally, Formula (I) discloses that R_1 "is a substituted or unsubstituted aryl group, preferably substituted or unsubstituted phenyl or naphthly...." As such, the '640 patent does not teach or suggest a compound where the R_1 is selected from the group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. In contrast, Applicants' invention, as presently claimed in independent claims 1 and 8, relates to a charge transport material having the formula



where R comprises a hydrogen, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group and X comprises an arylamine group selected from the group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. Thus, the '640 patent does not disclose or suggest all of the features of Applicants' invention, as presently claimed in independent claims 1 and 8. Additionally, since the '526 patent alone or in combination with the '640 patent does not disclose or suggest the use of the claimed change transport materials, the '526 patent does not make up for the deficiencies of the '640 patent. Since the combination of the '526 patent and the '640 patent does not disclose or suggest all of the features of Applicants' claimed invention, the combination of the '526 patent and the '640 patent does not render Applicants' invention, as claimed in independent claims 1 and 8, prima facie obvious.

Since the combination of the '526 patent and the '640 patent does not render Applicants' claimed invention prima facie obvious, Applicants respectfully request the withdrawal of the

rejection of claims 7-9 and 14 as being unpatentable over the '526 patent combined with the '640 patent.

3. Rejections Over Goto Combined With Additional Teachings of Goto

The Examiner rejected claims 4 and 24 under 35 U.S.C. § 103(a) as being unpatentable over the '640 patent. Claims 4 and 24 depend from claims 1 and 21, respectively, and therefore incorporate all of the features of the respective independent claims. As discussed above, the '640 patent does not disclose or suggest all of the features of Applicants' invention, as presently claimed in independent claims 1 and 21, and therefore does not render claims 1 and 21 prima facie obvious. As such, Applicants respectfully request the withdrawal of the rejection of claims 4 and 24 as being unpatentable over the '640 patent.

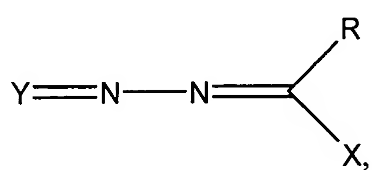
Additionally, the Examiner rejected claim 11 under 35 U.S.C. § 103(a) as being unpatentable over the '526 patent combined with the '640 patent. Claim 11 depends from independent claim 8 and therefore incorporates all of the features of claim 8. As discussed above, the combination of the '526 patent and the '640 patent does not render Applicants' invention, as claimed in independent claim 8, prima facie obvious. As such, Applicants respectfully request the withdrawal of the rejection of claim 11 as being unpatentable over the '526 patent combined with the '640 patent.

4. Rejections Over Hamasaki Combined with Goto

The Examiner rejected claims 1, 2, 5, and 6 under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent 6,528,645 to Hamasaki (the '645 patent) combined with the '640 patent (Goto). More specifically, the Examiner asserted that the '645 patent "discloses a single-layered organic photoreceptor comprising an electrically conductive substrate and a

photosensitive layer comprising a particular titanyl phthalocyanine crystals, an electron transferring compound, and a hole transferring compound." The Examiner also noted that the '645 patent "does not exemplify a single-layered organic photoreceptor comprising the charge transport compound recited in the instant claims." Applicants submit that the combination of the '645 patent and the '640 patent does not render Applicants' invention, as presently claimed in independent claim 1, prima facie obvious. Applicants respectfully request reconsideration of the rejection based on the following comments.

As discussed above, Compound (11) of the '640 patent comprises a N,N-diethylamine-4-naphthylene group at one end of the compound. Additionally, Formula (I) discloses that R_1 "is a substituted or unsubstituted aryl group, preferably substituted or unsubstituted phenyl or naphthly...." As such, the '640 patent does not teach or suggest a compound where the R_1 is selected from the group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. In contrast, Applicants' invention, as presently claimed in independent claim 1, relates to a charge transport material having the formula



where R comprises a hydrogen, an alkyl group, an alkenyl group, a heterocyclic group, or an aromatic group and X comprises an arylamine group selected from the group consisting of a carbazole group, a julolidine group and a p-N,N-diphenylaminophenylene group. Additionally, since the '645 patent alone or in combination with the '640 patent does not teach or suggest the claimed charge transport materials, the '645 patent does not make up for the deficiencies of the '640 patent. As such, the combination of the '645 patent and the '640 patent does not teach or

suggest all of the features of Applicants' invention, as claimed in independent claim 1, and therefore does not render Applicants' claimed invention prima facie obvious.

Since the combination of the '645 patent and the '640 patent does not render Applicants' claimed invention, prima facie obvious, Applicants respectfully request the withdrawal of the rejection of claims 1, 2, 5, and 6 under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent the '645 patent combined with the '640 patent.

5. Rejections Over Ohkubo Combined With Hamasaki and Goto

The Examiner rejected claims 7-9 and 12-14 under 35 U.S.C. § 103(a) as being unpatentable over the '526 patent (Ohkubo) combined with the '645 patent (Hamasaki) and the '640 patent (Goto). As discussed above, the '640 patent does not disclose or suggest Applicants' claimed charge transport material, as presently claimed in independent claims 1 and 8. Additionally, neither the '526 patent nor the '645 patent alone or in combination with the '640 patent disclose or suggest the claimed charge transport materials, and thus do not make up for the deficiencies of the '640 patent. Therefore, the '526 patent combined with the '645 patent and the '640 patent does not render Applicants' invention, as claimed in independent claims 1 and 8, prima facie obvious. As such, Applicants respectfully request the withdrawal of the rejection of claims 7-9 and 12-14 under 35 U.S.C. § 103(a) as being unpatentable over the '526 patent (Ohkubo) combined with the '645 patent (Hamasaki) and the '640 patent (Goto).

Applicants do not comment further on specific features of the dependent claims, but do not acquiesce to the assertions in the Office Action, since these issues are presently moot in light of the above analysis.

CONCLUSION

In view of the foregoing, it is submitted that this application is in condition for allowance. Favorable consideration and prompt allowance of the application are respectfully requested.

The Examiner is invited to telephone the undersigned if the Examiner believes it would be useful to advance prosecution.

Respectfully submitted,

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US PATENT SUBCLASS 536 / 26.11
.~.~.~.~.~ The phosphorus is part of a ring

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DEFINITION

Classification: 536/26.11

The phosphorus is part of a ring:

(under subclass 26.1) Compounds wherein the phosphorus is part of a ring structure.

(1) Note. Examples of compounds provided for herein are: [figure]

EXAMPLES

Organic Chemistry

Kosmoi.com > Science > Chemistry > Organic:

Organic chemistry is the branch of chemistry concerned with the study of carbon-containing molecules known as organic compounds. (except carbon dioxide and monoxide. Although there is an overlap with biochemistry, the latter is the specific study of the molecules made by living organisms.

Some of the classes of substances studied in organic chemistry include: aliphatic compounds which deals with chains of carbon which can be modified by functional groups; aromatic compounds which are compounds having a benzene ring or similar group; heterocyclic compounds, compounds which include non-carbon atoms as part of a ring structure; physiologically active compounds which have an effect on the human body; and polymers - long chains of repeating groups.

Aliphatic compounds

Hydrocarbons -- Alkanes -- Alkenes -- Halogenoalkanes - Alcohols -- Ethers -- Aldehydes -- Ketones - Carboxylic acids -- Esters -- Carbohydrates -- Alicyclic compounds -- Amines -- Amides -- Amino acids

Aromatic compounds

Arenes or Aromatic hydrocarbons -- Benzene -- Aromatic amines -- Phenols

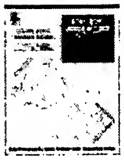
Heterocyclic compounds

Pyrrole -- Porphyrin -- Chlorin -- Corrin

Physiologically active compounds

Organic, a...

Karen C. Timberlake



Strategic Applications of Named Reactions in Organ...
Laszlo Kurti, Barbara Czako

Shaum's Outline Of General, Organic and Biological...
George Odian, Ira Blei

Advanced Organic Chemistry: Structure and Mechanis...
Francis A. Carey, Richard J. Sundberg

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Polymers

Polymer -- condensation polymer

Concepts

Organic nomenclature -- Chemical formula -- structural formula -- skeletal formula --Organic reactions

History

For some time it was believed that organic compounds could be produced only by living organisms (hence the name) until the synthesis of urea by Friedrich Wöhler in 1828.

Characterisitics of organic substances

The reason that there are so many carbon compounds is that carbon has the ability to form many carbon chains of different lengths, and rings of different sizes. A lot of carbon compounds are extremely sensitive to heat, and generally decompose below 300'C. They tend not to be so soluble in water compared to many inorganic salts. In contrast to such salts, they tend to be much more soluble in organic solvents such as ether or alcohol. Organic compounds are covalently bonded.

More on Organic_chemistry

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The Cell Wall

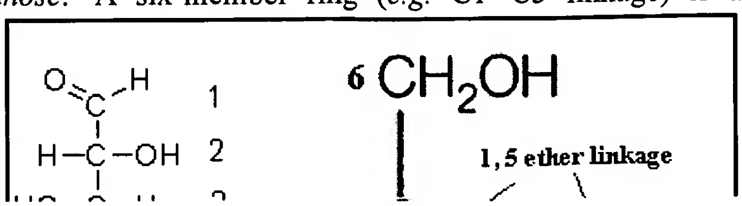
A Spoonful of Sugars

Terms defined on this page:	
anomer **enantiomer** **furanose** **glucan** **glucose** **glycoside** **Haworth diagram**	**hemiacetal** **hydroxyl group** **ligand** **mannose** **polysaccharide** **pyranose** **stereochemistry**
These would be on the test, if we gave one.	

Since we haven't done this elsewhere, it's time we provided the rudiments of sugar (saccharide) chemistry, so that we can make useful noises about *polysaccharides* (sugar polymers) -- easily the most common class of biopolymers on the planet. A more extensive and far better introduction may be found at **Natural Products**.

All sugar monomers of biological importance have structural formulas which looks something like this: $CH_2OH\text{-}(CHOH)_n\text{-}CHO$. In other words, they consist of a chain of carbon atoms, in which each carbon atom has a *hydroxyl* (-OH) group attached to it, except for C1 (sometimes C2) which has an aldehyde or keto (=O) group. In living organisms, the chain is generally 3-7 carbons long. In biologically important polysaccharides, the monomers are almost always 5- or 6-carbon sugars.

We have only reluctantly provided a reference graphic of a sugar monomer in linear form because, in life, 5- and 6- carbon sugars rarely occur as straight chains. The carbon atoms with the aldehyde (or keto) group reversibly bonds to one of the other carbons by "sharing" a hydroxyl oxygen, forming a C-O-C linkage. This is known as an *hemiacetal* linkage. Typically, the result is a 5- or 6-member ring -- four or five carbon atoms plus the linking oxygen. A five-member form (*e.g.* a C1→C4 linkage) form is called a *furanose*. A six-member ring (*e.g.* C1→C5 linkage) is a *pyranose*. A simple example, and perhaps the most common sugar monomer, is *glucose*. Its usual (pyranose) ring form is shown in the image. It can also occur as a furanose.



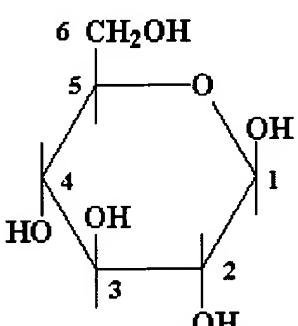
In fact, the two forms are in equilibrium.
Under biologically relevant conditions, the equilibrium so strongly favors the pyranose form of glucose that we can ignore the furanose. However, this is not necessarily the case for all sugars.

This is also the last time we will show the ring carbons. By the universal convention of biochemists, carbon atoms forming part of a ring structure are not shown with a 'C' symbol. They are simply indicated by the intersection of the bonds from the various groups (*ligands*) to which the carbon atom is attached. Very frequently, hydrogen ligands (H-) are not shown either. A line with nothing at the end means a hydrogen ligand, and an unlabelled intersection of bonds means a carbon atom. See examples below.

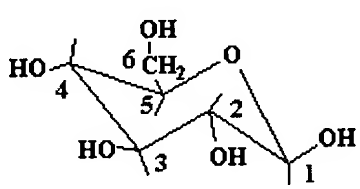
Sugar monomers are not always quite this simple. Each of the hydroxyl ligands is moderately chemically active, and all kinds of variants exist. An example, of particular relevance to fungi, is chitin. Chitin is a polymer of N-acetly-2-glucosamine, *i.e.*, a glucose derivative in which the ligand CH_3-CH_2-NH- substitutes for the OH-group on C2. See the *chitin* glossary entry for an image.

In most of these examples, we have shown the structure of sugars using a *Haworth Diagram*. These are easy to draw and to understand, but they are rather crude tools because the bond angles are grossly distorted. Carbon normally forms tetrahedral structures, with the bonds about 108° apart. However, Haworth diagrams will do for our purposes, so long as we don't take them too seriously.

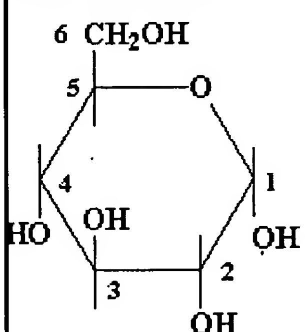
Stereochemistry



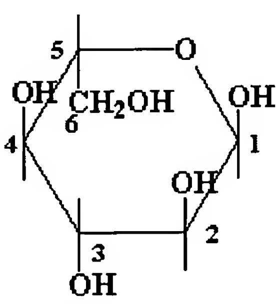
β-D-glucose in the usual abbreviated format



β-D-glucose in another popular format, with more realistic bond angles



α-D-glucose



α-L-glucose: note that the C1 hydroxyl points up for this enantiomer.

The figure above is labeled "**D**"-glucose for an important reason: it gives us an excuse to discuss three quick points about *stereochemistry*. Stereochemistry relates to the properties of compounds which are chemically identical, except that they are asymmetrical, and differ in the arrangement of ligands about one or more asymmetrical backbone atoms.

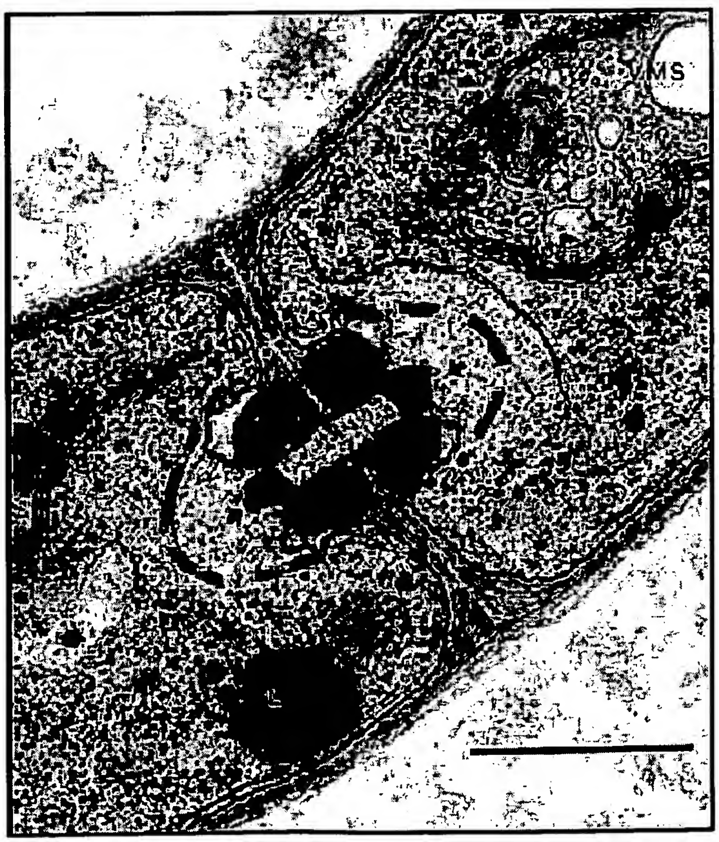
(1) Note that carbons 1 through 5 are asymmetrical in glucose. Each of these carbons is attached to four *different* ligands. Thus, the relative positions of the groups attached to the carbon atoms makes a difference. If, for example, we flipped the hydroxyl group on C2 so that it was *above* the ring, this would no longer be glucose. It would be *mannose*, a sugar with rather different chemical properties.

(2) If we took the mirror image of the *entire* molecule, all of the bonds would be in the same

relative position. Thus we would have a molecule that ought to have exactly the same chemical properties as glucose, which it does -- sort of. The difficulty is that, when this reversed glucose interacts with some other asymmetrical biochemical, the two molecules no longer mesh in the same way. Consequently, we must distinguish between **D**-glucose and its mirror image (*enantiomer*), **L**-glucose. Don't worry about telling the difference. The biologically relevant form for sugars is usually the **D**-enantiomer. You can assume a figure shows the **D**-enantiomer unless someone tells you differently.

(3) C1 is a special case. In the linear form, C1 is not asymmetrical because it has only three ligands. However, when the C1 forms a pyranose linkage to C5, it becomes asymmetrical. In terms of our diagram, the -OH group on C1 might point down or up. Free glucose in solution is, once again, in equilibrium between the two forms, referred to as α- and β-**D**-glucose. These alternate forms of the hemiacetal are referred to as *anomers*. However, this time, neither form is strongly favored. (This is also not like the glucose-mannose example, since the two forms freely interconvert.) For free glucose, the exact form at any given time is unimportant. However, when glucose is linked to another sugar through the C1 hydroxyl group, the conformation becomes "frozen." Consequently, for glucose *polymers*, we need to distinguish between α (hydroxyl down) and β (hydroxyl up) linkages (*glycoside bonds*). Incidentally, the alpha-down/beta-up convention is reversed for **L**-enantiomers or, naturally enough, when the sugar monomer is represented upside-down.

General Features



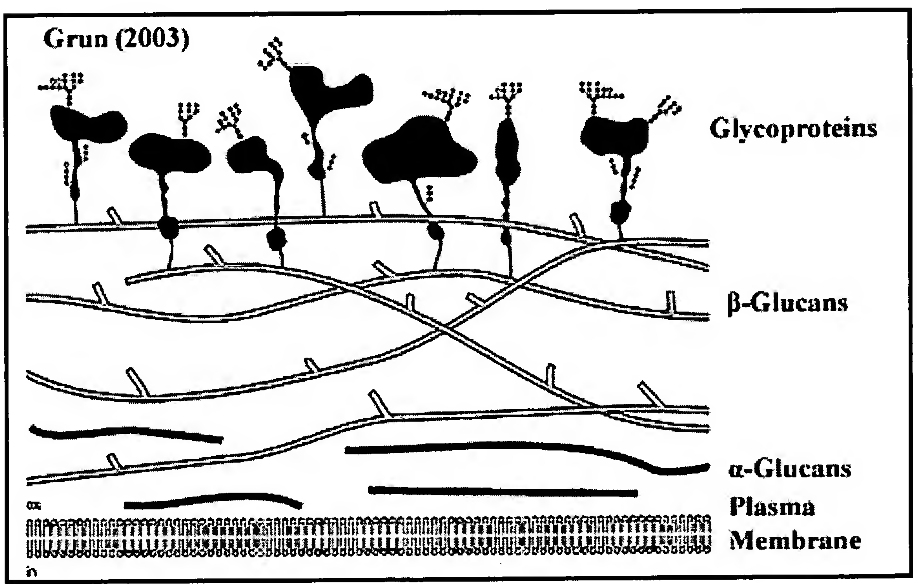
Fungal cells maintain a very high turgor pressure, so the integrity of the cell wall is a critical matter. Cabib *et al.* (2001). The composition of the fungal cell wall is rather variable. The variability appears to have phylogenetic significance, but few, to our knowledge, have followed that trail (*but see* Grun, 2003). In general, mycology has leapt directly from the ponderous fallacies of classical typological systematics to the facile, but sometimes equally fallacious, paradigms of molecular systematics. Consequently, there is remarkably little honest biology and biochemistry being applied to phylogenetic issues.

The situation is not improved by the usual non-specialist texts which characterize the fungal cell wall as a relatively simple structure made up of "cellulose" and chitin. Consider that the fungal cell wall can make up 30% or more of the dry weight of the fungus, and that the fungi are characterized by external digestion of food followed by selective absorption of the digestion products. Clearly, we can expect that the fungal cell wall will be a complex, specialized system.

It is all that; and, in addition, it is a highly dynamic system, constantly being regenerated and remodeled according to the needs of the moment. Adams (2004). Thus, many of the cell wall-associated proteins are enzymes whose function is to hydrolyze chitin and polysaccharides. The lesson is that this type of cell wall is, from a metabolic point of view, very different from insect exoskeletons or a plant cell walls, which are terminally differentiated structures.

Not unexpectedly, attempts to understand the biosynthesis of cell wall components have run into a maze of regulatory pathways which are difficult to sort out. García *et al.* (2004) applied brute force genomics methods to analyze gene responses to several different physical and chemical agents affecting cell wall integrity. The genetic responses in each case involved on the order of 100 different genes, with a significant different cohort of genes activated by each agent. Similarly, Lesage *et al.* (2004) identified 135 genes involved in the synthesis and regulation of the β-(1→3)-glucan component (*see infra*) alone (*see also* several similar studies cited by these authors). In fact, it has been estimated that 20% of the *Saccharomyces* genome is involved with cell wall biosynthesis. Durán & Nombela (2004). Some efforts are being made to pare these lists down to some "core" group of pathways. However, the magnitude of the problem has only become clear in the last few years, and it is much too early to say anything useful.

Structure



We include two diagrams of the fungal cell wall by Grün (2003) and Cabib *et al.* (2001). We've also thrown in Joan Miró's (1940) *Chiffres et Constellations* just because it has somewhat the same feel to it.

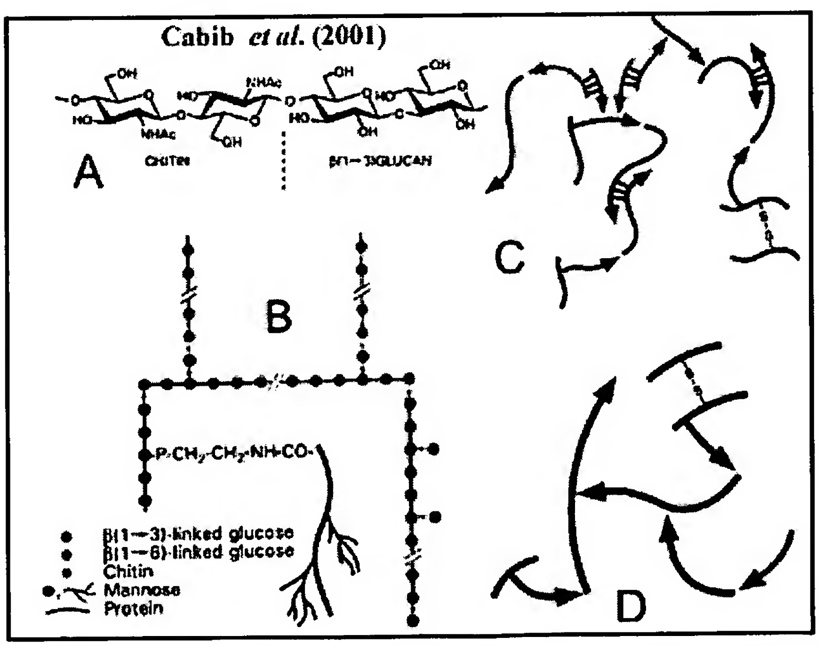
While each of these images speaks to us in its own way, we will work primarily with Grün's concept. The cell wall is generally constructed of three layers: (1) an α-glucan layer (a *glucan* is a polymer of glucose), (2) a β-glucan layer, and (3) an outer layer of glycoprotein. In addition, *chitin* may be a significant component of certain cell wall structures.

The α-glucan layer, if present, is generally composed of the α(1→3)-glucan polymer. However, α (1→4) glycosides are variably present. *Compare* glycogen, which is α(1→4)-glucan with (1→6) side chains. Where present, the α-glucan material appears as a fibrillar layer adjacent to the plasma membrane and is thought to serve a largely structural role, stiffening the basal layer of the cell wall.

The α-glucan layer is rarely represented in diagrams of the fungal cell wall because it does not occur in *Saccharomyces*, which is the usual model system. In fact, it has a rather peculiar

phylogenetic distribution. Among ascomycetes, the alpha glucan is found in *Schizosaccharomyces*, but is not known from any other yeasts. The material is common among all groups in the Pezizomycotina. However, in Lecanoromycetes, a very large proportion tends to be in the α(1→4) form. Alpha glucans also form a significant, sometimes even dominant, part of the cell wall in many basidiomycetes, but are completely absent outside the Hymenomycetes. Grün (2003). Although *Schizosaccharomyces* is often classified with the yeasts, its position is probably more basal. A number of studies show it branching with (paraphyletic) taphrinomycotines. *See, e.g.*, Liu *et al.* (1999), An *et al.* (2002). We tend to prefer the methodology of these studies, which are neither biased by the superficial similarities of "yeast" forms nor confused by the usual problems with *rDNA* and *mtDNA*. Thus, it appears likely that the alpha glucan layer is primitive for all higher fungi, or at least for Ascomycota, with subsequent multiple losses.

The bulk material of the cell wall is usually in the form of β(1→3)-glucan. This forms a very stable hydrogen-bonded triple helix in solution, and probably *in vivo*. The packing of these triple helix structures appears to be controlled by the size and frequency of very short (1→6) side chains, sometimes consisting of only a single glucose monomer. Grün (2003). If so, this clearly provides a method for controlling the structure and conformation of the cell wall very simply and with very fine, localized control. However, essentially no work appears to have been done in this area. If anyone out there is looking for a potentially elegant and informative dissertation topic in a virtual research vacuum, this is it.



In addition to β(1→3)-glucan, the cell wall contains β(1→6)-glucan. We emphasize that this is not simply a β(1→3)-glucan with big side-chains, but a polysaccharide with a true β(1→6) backbone. This material may be peripheral to the bulk β(1→3)-glucan and is, in any case, strongly involved in cross-linking the various components of the cell wall, as shown in the figure from Cabib *et al.* (2001).

The outermost layer of the cell wall is composed of diverse proteins bearing polysaccharide side chains composed of mannose. The usual explanation is that these are attached through their mannan side

chains via a (1→3) linkage with the β(1→6)-glucan. However, this is only a model. Real life appears to be very much more complex, involving a wide variety of different interactions between glycoproteins and bulk cell wall materials. Pitarch *et al.* (2002).

Finally, the fungal cell wall contains variable amounts of *chitin*. In many systems chitin is a major constituent of the cell wall. In others, it is involved only in cell division or reproductive structures and is virtually absent otherwise. Again. we are reluctant to say much about it, absent more detailed, phylogenetically-grounded studies of the actual ultrastructure in particular cases.

In general, the study of the fungal cell wall tends to be strong on models and somewhat weaker on data. One virtue of the brute force genomic and proteomic studies now being produced is that they clearly confront us with the scope of the problem. Fungal cells probably lack the diversity of metazoan tissues. However, each fungal cell must, for that very reason, be competent to perform a much wider variety of functions than a typical terminally-differentiated metazoan cell. Consequently, their superficial similarity and simplicity are likely to mask a very complex, plastic biochemical repertoire. Perhaps, after all, the Miró is the best representation, given the current state of our knowledge. ATW051113.

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